

**Committee on Science
U.S. House of Representatives
Hearing Charter**

Lunar Science & Resources: Future Options

**Thursday, April 1, 2004
1:00 p.m.
2318 Rayburn House Office Building**

1. Purpose

On Thursday, April 1, 2004 at 1:00 p.m., the Subcommittee on Space and Aeronautics will hold a hearing to examine current thinking about the suitability of the Moon for scientific and commercial activities.

The hearing is not meant to focus on whether to go to the Moon, but rather is intended to examine the suitability of using the Moon for an extended – perhaps permanent – presence to conduct space science and resource-extraction activities.

2. Witnesses

- **Dr. Paul Spudis** is a Senior Staff Scientist at the Johns Hopkins University Applied Physics Laboratory and Visiting Scientist at the Lunar and Planetary Institute in Houston, Texas.
- **Dr. Daniel F. Lester** is a Research Scientist at the McDonald Observatory, University of Texas at Austin.
- **Dr. Donald Campbell** is a Professor of Astronomy and associate director of the National Astronomy and Ionosphere Center (NAIC) at Cornell University.
- **Dr. John S. Lewis** is a Professor of Planetary Sciences and Co-Director of the Space Engineering Research Center at the University of Arizona.
- **Dr. Timothy Swindle** is Professor of Geosciences and Planetary Sciences at the University of Arizona.

3. Overarching Questions

1. Is the Moon a uniquely useful site to base deep-space radio, infrared and optical telescopes or other science instruments?
 - a. Can space science be conducted using instruments on the Moon more reliably and cheaply than it could be done from earth or using satellite-based instruments? What other fields of science (i.e., astrobiology, cosmology) would benefit from using a Moon-based laboratory?

2. Does the Moon contain minerals, isotopes, or other materials that one day may be commercially exploitable? How much certainty is there about the presence and quantity of these resources? How readily extractable are they?
 - a. What additional technologies, if any, must we first develop before these resources can be made useful?

4. Background

On January 14, 2004, President Bush announced his Space Exploration Initiative, putting in motion a major new NASA program to send astronauts to the “Moon, Mars and beyond.” Among other goals, the plan states: “The extended human presence on the Moon will enable astronauts to develop new technologies and harness the Moon’s abundant resources to allow manned exploration of the challenging environments... Experience and knowledge gained on the Moon will serve as a foundation for human missions beyond the Moon, beginning with Mars.”¹

The Space Exploration Initiative calls for the first launch of a robotic probe to the Moon in 2008 to begin mapping and reconnaissance studies. At least one probe will be launched each year thereafter, either an orbiter or lander, with the goal that the first manned Moon mission would occur between 2015 and 2020. While the Space Exploration Initiative establishes a goal of going back to the Moon, it does not specify what we would do once we get there (i.e., lunar geology, space telescopes, mining).

The initiative is silent on whether the U.S. would attempt to establish a permanent human presence on the Moon. But proponents of such a presence believe the time is ripe to advocate lunar bases – robotic or human tended – as a logical next step of any U.S. effort to return to the Moon.

Some members of the lunar science and astronomy communities have long viewed the Moon as a base from which to operate telescopes and other science instruments. The Moon offers several clear advantages – and disadvantages – as a base for astronomical observatories. Advantages include the lack of an atmosphere, its ability to shield instruments from radio and thermal pollution of Earth, lack of a magnetic field, a solid surface, and, in lunar craters at the poles, the capability of keeping infra-red telescopes operating at optimally cold temperatures.

Disadvantages include dust, the need to install power sources to run instruments, and the risk of landing payloads safely on the Moon. Human-tended operations pose challenges that are far greater, such as assuring a reliable supply of food, water and oxygen; developing a suitable shelter; high background radiation; the risks of launching and landing; working in a cold vacuum; and the prolonged effects of operating in a low-gravity (one-sixth of Earth’s) environment.

¹ “President Bush Announces New Vision for Space Exploration Program.”
www.whitehouse.gov/news/releases/2004/01/20040114-1.html

Some scientists believe the Moon contains large deposits of minerals and isotopes that one day may be commercially exploitable. Of most interest is the possible presence of water, and the presence of Helium-3, which theoretically could be used on Earth to generate energy using fusion reactors.

The attached article from the March 12, 2004 edition of *Science Magazine* outlines the debate on possible activities that could be conducted on the Moon.

5. Issues

- **How much water is on the Moon and how difficult would it be to extract?** In 1994, the U.S. lunar orbiter *Clementine* found indications of frozen water at the Moon's poles. Scientists disagree on whether water is actually present, and, if it is, whether it exists in significant quantities. Obviously, water would be a boon to any human activities on the moon because it could be used to sustain human life and to produce hydrogen fuel and oxygen. If no readily accessible source of water is found, lunar astronauts would need to transport their own water, significantly adding to the logistics burden and possibly limiting the amount of other materials they could bring along, as well as limiting the time they could remain on the Moon.

Water can be transformed into fuel (hydrogen) and oxygen, but exploiting this opportunity requires launching heavy processing equipment from Earth, safely landing and assembling it on the lunar surface, and providing power for its operation. Would benefits of this approach outweigh the costs of simply launching fuel and oxygen from Earth? Would the lack of easily extractable lunar ice prove to be an insurmountable obstacle to long-term human habitation?

- **Do the advantages outweigh the disadvantages of using the Moon as a base for astronomical observatories? How does the Moon compare with other alternatives?** Scientists disagree about the benefits of using the Moon as a site for operating science instruments that are designed to look into deep space. Astronomical observatories located on the Moon's far side, or at its poles, hold many advantages over Earth-based observatories. Having no atmosphere eliminates a major source of aberrations common to Earth-based telescopes and it permits viewing objects at all wavelengths (Earth's atmosphere filters out ultraviolet, x-ray, and gamma ray wavelengths). The Moon would also act as a shield against radio and thermal pollution from Earth sources. Its uniformly low temperatures at the lunar poles provide an excellent location to site infra-red telescopes.

Disadvantages include the threat of lunar dust settling on, and obstructing telescope optics. Dust may be kicked up during landing, assembly, or repair. The risk of safely landing the telescope is substantial. Providing power to run the instruments will require construction of solar arrays or the use of a small nuclear-electric generator at a location far enough away to avoid interference. Relying on

lunar astronauts to assemble the observatory raises significant risk factors, especially if they are expected to work at the bottom of a deep, cold crater.

Some scientists advocate free-flying telescopes (such as Hubble, the Chandra Observatory, and the newly commissioned Spitzer Infra-red Observatory) as a more cost-effective, less risky alternative than lunar-based telescopes. With the exception of Hubble, none of the observatories are designed to be serviced or repaired, eliminating any need for human tending. Free flyers can be launched to high Earth orbits or libration points, removing a large source of thermal and radio interference. Guidance, pointing and tracking technologies are extremely accurate, negating any advantage of using a stable lunar surface.

- **Is it commercially practical to mine lunar-based minerals and isotopes?** Scientists disagree about the amounts and types of valuable ores that may be found on the Moon. A related issue is whether commercial enterprises can overcome the huge costs associated with launching, landing and assembling foundries and fabrication facilities to mine and process any ores, and transport finished products to Earth or use them to support missions to other parts of the Solar System. Once again, the availability of lunar ice (water) would affect the success of such activities.

Harvesting resources on the Moon would also raise several important legal questions (about which the Committee intends to hold a future hearing). The United States is a signatory to four multinational treaties concerning the use of outer space, two of which expressly mention the Moon. The Treaty on Principles Governing the Activities of States in the Exploration of the Use of Outer Space, including the Moon and Other Celestial Bodies was codified in 1967 and ratified by the United States, Russia and 96 other nations. Among other things, the treaty provides that the Moon is "not subject to national appropriation." The United States is not a signatory to the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ("the Moon Treaty"). Codified in 1979 and ratified by only seven nations, the Moon Treaty states in relevant part that the Moon is "the common heritage of all mankind," and that the moon's natural resources may not become the property of any person. The treaty further provides for an international regime to govern the "exploitation of the natural resources of the Moon."

How practical is it to consider extracting Helium-3 for power generation facilities on Earth? Helium-3 is a scarce isotope on Earth but lunar samples returned by Apollo missions suggests that it is more abundant on the Moon's surface. While it may more plentiful, extracting large amounts of Helium-3 from lunar soil is likely to prove difficult. Physicists believe Helium-3 will one day be used as a fuel for specially designed fusion reactors on Earth, but development of such reactors is decades away.

6. Questions to Witnesses

In his letter of invitation to appear as a witness, Dr. Spudis was asked to address the following questions in his testimony:

- What science can be conducted on the surface of the Moon that cannot be duplicated by Earth-based research or free-flying satellites?
- What minerals, elements and isotopes exist on the Moon in sufficient quantities that they could contribute to expanding the reach of human exploration of the solar system? What is the basis of your estimate and how widely shared is it? How soon after a human return to the Moon would it be possible to begin exploiting resources?
- How much water do you believe is trapped on the Lunar surface, and what is the basis of your estimates? How confident are you of these estimates? Based on current observations, is the water concentrated in various pockets on the Lunar surface, or is it widely distributed?
- Do you believe that long-term human habitation on the Moon is necessary to conduct science and lunar resource extraction activities? What role would robotics play?

In his letter of invitation to appear as a witness, Dr. Lewis was asked to address the following questions in his testimony:

- What minerals, elements and isotopes exist on the Moon in sufficient quantities that they could contribute to expanding the reach of human exploration of the solar system? What is the basis of your estimate and how widely shared is it? How soon after a human return to the Moon would it be possible to begin exploiting resources?
- What are the advantages to human exploration of the solar system by siting fabrication and processing facilities on the Moon? Can Lunar-based fabrication be done more effectively than using Earth-bound facilities?
- How would you characterize the possibility that extraction of Moon materials may one day be commercially viable ?

In his letter of invitation to appear as a witness, Dr. Campbell was asked to address the following questions in his testimony:

- How much water do you believe is trapped on the Lunar surface, and what is the basis of your estimates? How confident are you of these estimates? Based on

current observations, is the water concentrated in various pockets on the Lunar surface, or is it widely distributed?

- How important is finding water to exploiting the Moon for scientific or economic purposes?
- What kinds of instruments need to be flown on upcoming Lunar probes to try to resolve questions about water on the Moon?
- What other minerals, ores, or elements do you believe may be present in the lunar soil that may hold interest for future exploitation?

In his letter of invitation to appear as a witness, Dr. Lester was asked to address the following questions in his testimony:

- What space science can be conducted on the surface of the Moon that cannot be duplicated by Earth-based research or free-flying satellites?
- Is the Moon an appropriate site for astronomical observatories? What advantages and disadvantages does the Moon pose as a base for telescopes?
- As NASA begins to launch lunar robotic probes to survey the Moon's resources, what instruments should be flown on the probes that can be used to serve the Space Exploration Initiative as well as inform lunar scientists about the suitability of using the Moon as a base for long-term science activities?
- What are your views about the practicality of establishing long-term human bases on the Moon to conduct science? Will robotics be able to carry out the same science missions without the presence of humans on the Moon?

In his letter of invitation to appear as a witness, Dr. Swindle was asked to address the following questions in his testimony:

- What are the most pressing questions in lunar science? To what extent do they require human lunar missions to be pursued? To what extent can they be pursued from Earth?
- What minerals, elements and isotopes exist on the Moon in sufficient quantities that they could contribute to expanding the reach of human exploration of the solar system? What is the basis of your estimate and how widely shared is it? How soon after a human return to the Moon would it be possible to begin exploiting resources?

- Specifically, how much Helium-3 do you believe is on the Moon, and what is the basis of your estimate? Based on current observations, is the Helium-3 concentrated in various pockets on the Lunar surface, or is it widely distributed? How much ore would have to be processed to refine useful amounts of Helium-3, and how technologically difficult would it be to accomplish? How long after a human return to the moon would production of Helium-3 likely be viable? How close are we to developing technologies that could make use of Helium-3?

7. Attachment

“Moon’s ‘Abundant Resources’ Largely an Unknown Quantity”, *Science Magazine*, March 12, 2004